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REPORT

A field strength measuring receiver for band II

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Summary

This Report describes a receiver designed for the investigation of reception conditions for both monophonic and stereophonic broadcasts using the pilot tone stereo system in the band 87 – 108 MHz. The design is intended to replace two earlier receivers¹ and, in addition, provides commercial quality stereo reception for assessment of the stereo service provided in any area. These requirements are somewhat conflicting and the resultant design here described is therefore a compromise. It is possible that extensive field use may lead to a reconsideration of this compromise. To meet this possibility the receiver has been made in modular form.

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1. Introduction

For some time past field strength measurements made by Service Planning Section in the UHF bands have been made with a receiver² which gives a digital readout of the field strength in decibels relative to $1 \mu\text{V/m}$.

These receivers have proved simple to use and have given consistent results over long periods. The same basic principles have therefore been included in the Band II receiver.

Any field strength measuring receiver must meet certain fairly stringent requirements. The most important of these can be summarised as follows:

- (a) Be easily and accurately tuned and maintain this state consistently; in addition, present day requirements call for rapid retuning to any required frequency.
 - (b) Have controls and indications which are simple to use and unambiguous. The controls must retain their settings over long periods and resist rough handling.
 - (c) Must have and maintain specified accuracy over a wide range of input levels (receiver law). This must be easily checked and adjusted.
 - (d) Must be capable of self calibrating in a consistent and stable manner over periods of several months since sets may be away from calibration facilities for long periods.
 - (e) Meet available power supply requirements — in practice this means the ability to operate either from the mains or from a vehicle battery. The receiver must maintain its calibration over wide variations and fluctuations in such supplies.
 - (f) Must be easily and quickly serviced.
 - (g) Have a wide temperature range over which the receiver will work, since equipment left in parked vehicles can rise to high temperatures in summer and drop to low temperatures in winter.
 - (h) Be portable, i.e. small in size and light in weight. It must resist fairly rough handling, so that it may be sent by train or aircraft with a minimum of packing and a minimal chance of damage during such transport.
- receiver remains on tune. The frequency is set on a series of decade switches and may be changed rapidly.
- (b) The control knobs are clearly marked and the switch handles are colour coded in line with other receivers with which the staff are familiar. Seven bar LED indicators are used for the displays and the rate of change of the figures is controlled so that hunting of least significant digit is not objectionable.
 - (c) The receiver law depends upon the value of resistances in the i.f. unit. Past experience with the UHF digital receiver indicates that the components chosen for this equipment will maintain the law over long periods.
 - (d) The calibration oscillator is locked to the local oscillator and has a close-tolerance levelling circuit which maintains the calibration output level constant within $\pm 0.1 \text{ dB}$ over the whole tuning range.
 - (e) All power supplies are derived from a high-frequency square-wave inverter operated from an 8 V D.C. regulated supply. This supply is obtained either from a vehicle battery or from the mains via a transformer and bridge rectifier, followed by a voltage regulator.
 - (f) The receiver is of modular construction so that units can be replaced quickly and repaired at leisure. Modules are further subdivided into 'throw-away' units.
 - (g) By careful design the overall temperature rise of the receiver has been kept to a minimum. A 30 Watt printed circuit heater operated by a simple thermostat, maintains the body of the receiver at 5°C provided the receiver is connected to a 12 V supply.
 - (h) The receiver is housed in a 'Major' case with a lockable lid. The case and framework are made of alloy for lightness but are sufficiently strong to need no further protection to prevent damage whilst in transit by rail or air.

A photograph of the prototype receiver is shown in Fig. 1.

2. Specification of the receiver

1. Frequency range	87 to 108 MHz in steps of 50 kHz using a synthesiser for the local oscillator.
Field strength range	From $2.5 \mu\text{V}$ to 2.5 V e.m.f. at the receiver input. In steps of 0.2 dB .
Input impedance	75 ohms.

These requirements have been met in the present receiver by:

- (a) A synthesised local oscillator using a 1 MHz crystal as the reference frequency. This ensures that the

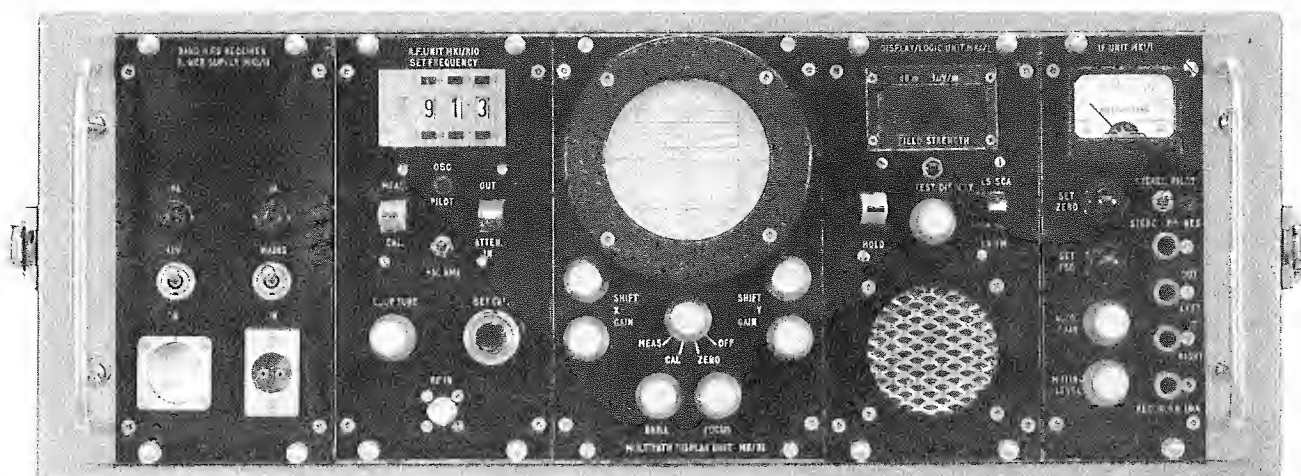


Fig. 1 - Exterior view of Band II field strength measuring receiver

Bandwidth	±130 kHz at -3 dB. ±300 kHz at -40 dB	supply or from 240 V 50 Hz mains. The current required from a 12 V supply is 3.75 A.
i.f.	10.7 MHz (oscillator low).	
Spurious responses	More than 45 dB below funda- mental.	Weight 11.5 kg.
Attenuators	26.0 dB of r.f. and 75.2 dB of i.f. attenuation is controlled by digital logic, a further 20 dB of r.f. attenu- ation is controlled by a front panel key.	Dimensions 530 x 330 x 300 mm.
Indicators	Digital display in decibels above 1 µV/m and meter.	
Meter output	An output jack for a recording milliammeter is provided.	
Audio output	Mono loudspeaker output. Stereo headphone output. Stereo outputs for feeding tape recorder or stereo loudspeaker amplifiers. Audio out- put muted during frequency selec- tion.	
Multipath	A multipath display unit is provided.	
Stereo indicator	A l.e.d. indicates whenever a 19 kHz pilot tone is present.	
Calibration oscillator	A self tracking calibration oscillator is provided.	
Remote aerial tuning	A zero to -10 V supply is provided for use with varactor-tuned loop aerials.	
Temperature range	0° C to 45° C.	
Power supplies	The receiver will operate from a 10 to 17 V negative earth vehicle	

3. Description

The receiver consists of five basic modules, these are:

1. The power supply unit.
2. The r.f. unit consisting of the r.f. tuner, synthesised local oscillator and calibration source.
3. The multipath display unit containing the display oscilloscope which shows FM deviation as a horizontal deflection and AM as a vertical deflection. This unit has a self contained supply unit and is provided with its own ON/OFF switch to save battery power and heat dissipation when not required. The unit also contains a suitable calibrator for the multipath display.
4. The display unit contains the field strength display, the main logic circuits and a small loudspeaker driven by the FM detector.
5. The i.f. unit — contains the measuring attenuator system, stereo decoder, audio output stages and a metering circuit for driving a chart recorder from the field strength display. Jacks are provided for stereophones, — left and right audio signals and for a recording milliammeter so that field strength can be recorded against either time or distance travelled by the measuring vehicle. Fig. 2 is a block schematic of the complete receiver.

3.1. The r.f. unit

From Fig. 2 it will be seen that the input signal from

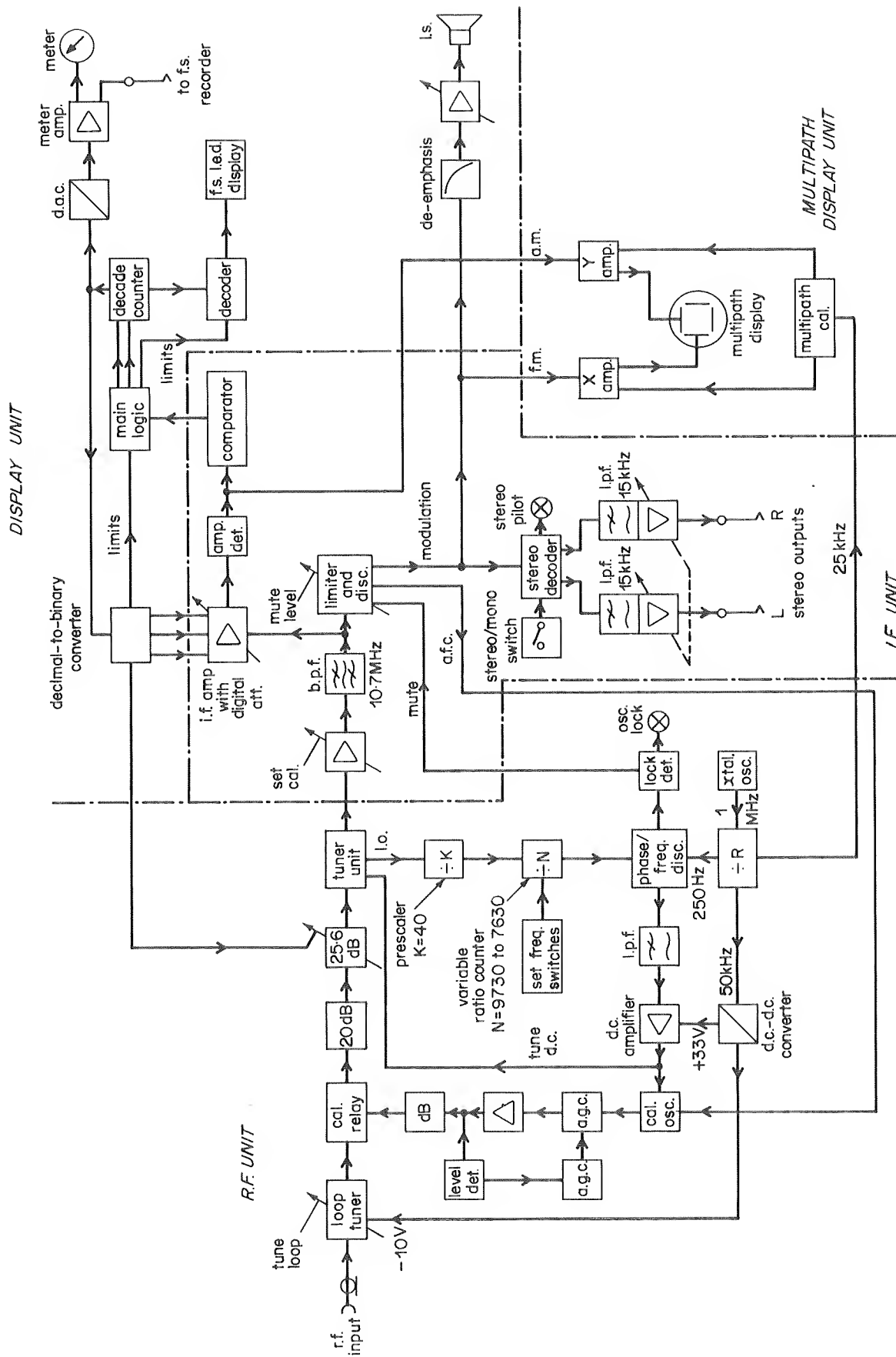


Fig. 2 - Block schematic

the aerial passes into the loop tuning circuit which enables a variable negative voltage to be fed via the feeder to the varactor diodes which tune the horizontal loops used for Band II field strength measurements. From here the signal is passed via the calibrator relay through two attenuators, one a 20 dB attenuator controlled by a key on the r.f. unit, the other a 26 dB pad which is switched in and out of circuit by the i.f. attenuator logic — the object of these attenuators being to prevent overload of the r.f. stage of the receiver by high inputs; the signal then enters the tuner module which consists of a tuned r.f. amplifier — mixer and local oscillator. All stages are tuned by varactor diodes to cover the band 87 MHz to 108 MHz with an intermediate frequency of 10.7 MHz. A small amount of the local oscillator output is extracted from the module and fed to the synthesiser prescaler ($\div K = 40$) which reduces the local oscillator frequency to a value suitable for the variable ratio divider ($\div N$).

The output of the $\div N$ circuit is compared in phase and frequency with the reference frequency provided by a 1 MHz crystal oscillator and its associated $\div R$ counter. Any resultant DC error voltage is filtered to remove the reference frequency components and applied to the local oscillator in such a way as to reduce the error voltage. The same voltage is also applied to the varactor tuning diodes of the calibration oscillator which is designed to track the r.f. input to the tuner for a 10.7 MHz intermediate frequency to within ± 100 kHz over the whole band — the tuning error of the calibration oscillator is further reduced by driving its varactor diode with an automatic frequency control (A.F.C.) voltage derived from the output of the i.f. limiter/discriminator. Thus the calibrator is rough-tuned by the synthesiser to the radio frequency to which the receiver is set and fine-tuned by the A.F.C. The calibration oscillator output is then amplified and applied under 'cal' conditions to the input of the receiver via a 75Ω attenuator. The input voltage to the attenuator is monitored by a level detector and the output of this is amplified and applied to the calibrator amplifier gain control stage, the loop gain of this AGC loop is such that the calibrator output is held constant over the tuning range to better than 0.2 dB, i.e. less than the smallest step the receiver can measure and display.

In this synthesiser the smallest frequency increment is 10 kHz and since K is 40 the reference frequency is 10 kHz/40 or 250 Hz, so that $R = 1 \text{ MHz}/250 \text{ Hz} = 4000$. Thus, for example, when the receiver is tuned to 87 MHz, the local oscillator frequency is $87 - 10.7 = 76.3 \text{ MHz}$ and the output of the $\div K$ is $76.3/40 = 1.9075 \text{ MHz}$. Since N must divide this down to 250 Hz $N = 1.9075 \times 10^6 \div 250 = 7630$.

The tuning switches will be set at 8700 (the required radio frequency). The output of the tuning switches is therefore converted to the preset value required by the $\div N$ stages (7630) by means of a binary coded decimal (BCD) subtractor which subtracts 1070 (this being the intermediate frequency) from the switch settings. Since the highest radio frequency on this receiver is 108 MHz and the i.f. is 10.7 MHz no '100 MHz' divider stage is required in the $\div N$ circuit and therefore no tuning switch is provided for the 100 MHz steps — this function being implied when the tens

switch is not set to either 8 or 9, but the 100 MHz position of the tuning switch is indicated by an illuminated digit in the 100 MHz position of the switch. Thus, to tune to, say 105.4 MHz, the switches are set at 054 and the indicators on the switches read 1054. As no subtraction is involved in the 10 kHz section of the frequency switch the 10 kHz inputs of the subtractor have been brought out on preset switches on the synthesiser card, this enables the intermediate frequency to be altered at will in 10 kHz steps. This allows the use of i.f. ceramic filters which may not be centred exactly on 10.7 MHz. The settings of these switches is a laboratory adjustment made when the i.f. filter is fitted or if this subsequently drifts with ageing.

When the synthesiser has adjusted the local oscillator for frequency and phase agreement with the reference, the lock detector operates to light the 'OSC LOCK' to show that the set is tuned and at the same time the lock detector removes the mute applied to the discriminator output to silence the receiver whilst it is being tuned.

3.2. The i.f. and display units

In order to calibrate the receiver, the i.f. stage following the mixer is provided with a manual gain control ('Set Cal') which can vary the gain by about 10 dB. This is sufficient to allow for variation of receiver sensitivity (S factor) and aerial constant (K factor), so that the display can be made to read directly in decibels above $1\mu\text{V/m}$ during the field calibration of the receiver. Following the variable gain stage, a 200 kHz wide band-pass ceramic filter is used as the main selectivity determining network. After this the i.f. signal is split to feed:

- (a) The limiter and discriminator to provide the audio output and A.F.C. for the calibration oscillator.
- (b) The digital i.f. amplifier.

The discriminator output feeds the stereo decoder and the local loudspeaker amplifier and also provides the X signal for the multipath display.

The digital i.f. amplifier and logic-driven attenuator is similar to that described in Reference 2. It consists of four dual cascode amplifiers in cascade giving main attenuation steps of 25.2, 25.6, 12.8 and 6.4 dB respectively, and auxiliary steps by varying the emitter feedback of 3.2, 1.6, 0.8 dB on the first three stages and 0.4 and 0.2 dB on the final stage. The 25.2 dB step is switched synchronously with a 26.0 dB r.f. attenuator thereby producing a 51.2 dB step. All nine attenuator steps are switched in binary sequence by a decimal to binary converter so that the receiver gain is controlled in 0.2 dB steps over a range of 102.2 dB.

The i.f. output is then detected by the amplitude detector, the output of which is applied to the multipath Y amplifier and the comparator circuit. This circuit drives a decade counter followed by the decimal-to-binary converter and hence the i.f. gain in such a direction as to equate the rectified signal to the comparator reference. The decade counter therefore records the number of 0.2 dB steps

required for equality and, after decoding, displays the field strength on seven-segment l.e.d. indicators. The decade counter also drives a digital to analogue converter to operate a recording meter. The amplifier for this meter has full-scale and zero-setting controls which permit the recording meter range to be expanded from 120 dB FSD to 10 dB FSD and this range to be centred on any required value.

If the received signal falls outside the measuring range of the receiver, the decade counter will be driven to either its maximum or minimum count. These states are detected by limit gates on the counter and when invoked, blank out the field strength display and replace it with L or H to indicate that the signal level is too low or too high. On first switching the set on, or if the manual attenuator state is changed, the display is also blanked and the letter C is displayed to remind the operator that the calibration should be checked. When the calibration key is operated, the C signal is removed and the field strength display unblanked.

3.3. The multipath display unit

This unit displays amplitude versus frequency modulation on a small cathode ray tube, the f.m. output providing horizontal deflection and the amplitude modulation providing vertical deflection of the trace. The X and Y amplifiers are DC connected to the AM and FM detectors and biased so that, with no deviation and no AM, the spot is central on the tube graticule (see Fig. 3). The amplifier gains are so adjusted that the spot makes a horizontal excursion between marks on the graticule for ± 75 kHz deviation and similarly in a vertical direction for 100% amplitude modulation. In order to calibrate the multipath display, a four-position switch is provided:

Position 1: The Unit is off and unpowered.

Position 2 ('Zero'): DC levels are applied to the X and Y amplifiers, these levels having been set up in the laboratory to be equal to the outputs ob-

tained from the FM and AM detector operated with the appropriate signal — this position therefore defines the zero point on the graticule and the spot can be placed at this point in this condition using the X and Y shift controls.

Position 3 ('Cal'):

In this position a 6.25 kHz square wave is applied to both amplifiers, but the waveform applied to one amplifier is phase-shifted by 90° by deriving the 6.25 kHz from the output of a twisted-ring divide-by-four counter fed with 25 kHz derived from the reference divider (see Fig. 2). This signal produces four spots in a square formation and the level of the 6.25 kHz signals are controlled so that when the X and Y gain controls are correctly set, the four spots of the CRT trace lie on the corners of the graticule square.

Position 4: The 'measure' position in which the amplifiers are driven from the receiver AM and FM outputs.

Before examining the multipath display, the receiver is allowed to operate normally so that the digital attenuators can set the gain such that the mean signal level at the AM detector is correct. Then the 'hold' key is operated; this inhibits the digital attenuator so that any variation in signal strength with deviation is displayed as Y deflection on the CRT.

If the hold key is not used, the digital attenuators will act to reduce the apparent amplitude modulation. An additional check on the X calibration is provided by the ± 50 kHz mark on the graticule. This is the position the X trace should be centred about if the receiver is tuned without the use of the ± 50 kHz switch being involved and this switch is then operated. If, however, the carrier frequency of the required station contains a 50 kHz component, then the trace will be centred on the zero position and switching the 50 kHz switch off should shift the spot to the -50 kHz position. With a stereo transmission the 19 kHz pilot tone gives a line instead of a central spot.

For further information on the interpretation of multipath displays, the reader is referred to references 1 and 3.

3.4. Power supplies

The power supply unit provides stabilised supplies at +200 volts, +12 volts and +8 volts and unregulated supplies at +25 volts and 12 volts from the vehicle battery (12 volts with negative earthed) or from a 240 volts 50 Hz mains supply. Since this vehicle battery voltage may vary from 10 to 17 the supply is first regulated to 8 V by a switching regulator and the 8 volt supply used to drive a DC/DC converter to give +12 volts (regulated) +200 volts (regulated) and 25 volts (unregulated). The DC/DC converter is driven at 50 kHz derived from the reference crystal oscillator in the r.f. unit, which itself is energised from the +8 volt supply.

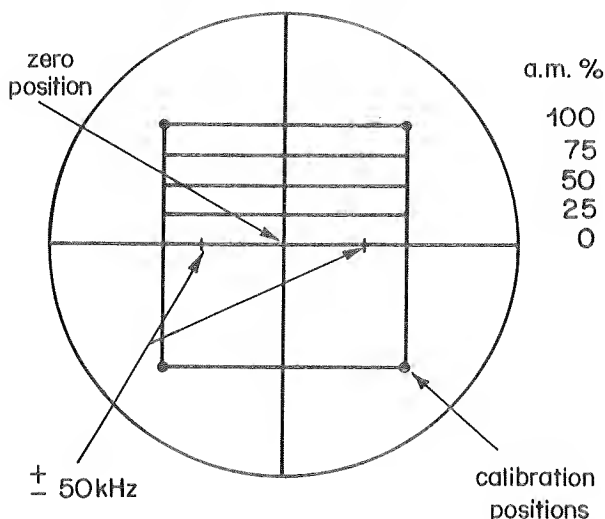


Fig. 3 - Band II F.S. receiver Mk. 1. Multipath display unit graticule

An additional supply circuit in the r.f. unit provides -10 volts regulated and +33 volts for the synthesiser and other bias functions and a separately switched supply is provided for the multipath display unit to produce -1000 volts and 6.3 volts for the cathode ray tube.

For mains operation a 12 volt transformer and rectifier act as a substitute for the vehicle supply. A safety diode prevents the mains unit from charging the vehicle battery if both supplies are switched on - this diode also prevents damage to the receiver should the vehicle supply polarity be wrong.

4. Performance

Tests carried out so far confirm that a reasonable compromise has been achieved between the various conflicting requirements of field strength measurement, multipath assessment and stereo reception.

In the field strength measuring mode, signals between 8 dB and 130 dB above $1\mu\text{V/m}$ can be measured over the whole of the band 87 MHz to 108 MHz with an accuracy of ± 1 dB. The synthesised local oscillator and the self-tuned calibration oscillator make the receiver both simple and easy to operate.

The multipath display is useful for assessing multipath propagation but it requires considerable experience to interpret the results from normal programme transmissions. The existence of the 19 kHz pilot tone tends to blur the display and unless a special transmission of low frequency-tone can be arranged it is difficult to estimate the path lengths involved. It is however, a very useful facility which will allow fuller appraisals to be made in future of VHF coverage.

In areas of high field strength where the 26.0 dB automatic r.f. attenuator is invoked the multipath display

becomes noisy. In order to overcome this a 'listen' key has been provided to lock the 26.0 dB r.f. attenuator out of circuit. This gives a less noisy display but may give rise to overloading of the r.f. unit unless due care is taken.

The stereo channel is designed for assessing defects in the stereo service caused by transmission conditions and is not designed as a quality monitor of programmes.

The performance of various parameters is given in Table 1 and Figs. 4 to 6.

TABLE 1

Channel separation (crosstalk)	See Figure 4
Channel balance. Volume control at max.	1 dB
Maximum output at 1 kHz into 600Ω	+5 dBm
Harmonic distortion at 1 kHz	See Figure 5
Frequency response with $50\mu\text{sec}$. de-emphasis (3 dB points)	20 Hz to 15 kHz
Signal to noise ratio	See Figure 6
Input level for stereo operation	See Figure 6

5. Conclusions

A versatile measuring receiver for f.m. transmissions has been produced and is now undergoing field trials. It has facilities for:

- Measuring field strength on a digital display
- Assessing stereo transmissions on headphones and has outputs for feeding a tape recorder.

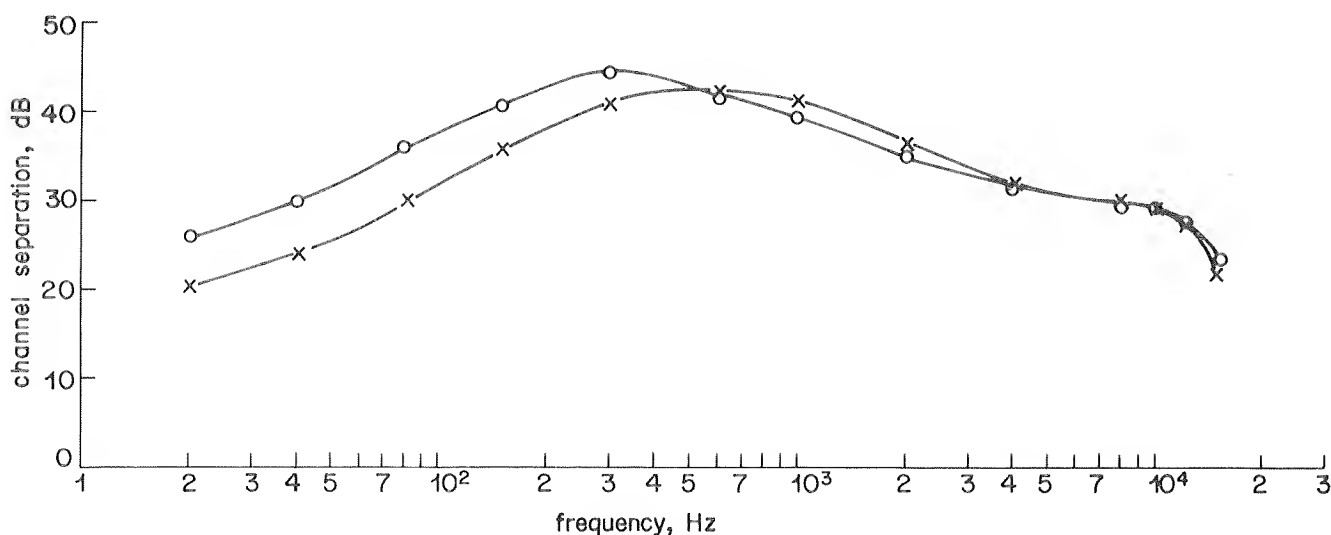


Fig. 4 - Channel separation V frequency

—○—○— L channel maximum output +5 dBm

—x—x— R channel maximum output +5 dBm

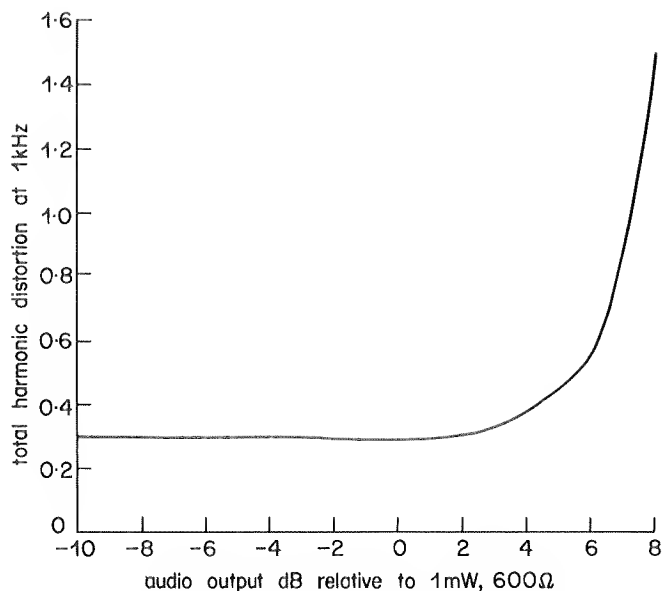


Fig. 5 - Total harmonic distortion v. audio output

R.F. input = 1 mV at 95 MHz

Modulation:— 75 kHz deviation at 1 kHz gives audio output of +8 dBm rel. 1 mW, 600Ω on both channels with stereo pilot on

- (c) Investigating multipath propagation.
- (d) Measuring field strength on a recording milliammeter.
- (e) Operating from either a 12 V battery or from 240 V, 50 Hz. mains.

The local oscillator is synthesised from a crystal reference source and hence no tuning adjustments are required once the frequency has been set.

The receiver replaces old equipment with consequent advantages of small size, less weight and less liability to

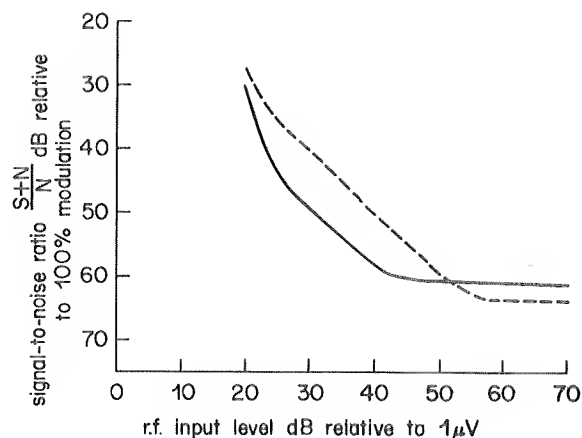


Fig. 6 - Signal to noise ratio v. RF input level

— Mono - - - - - Stereo

The signal to noise ratio is unweighted and measured in a bandwidth of 250 Hz to 15 kHz

operator error.

6. References

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